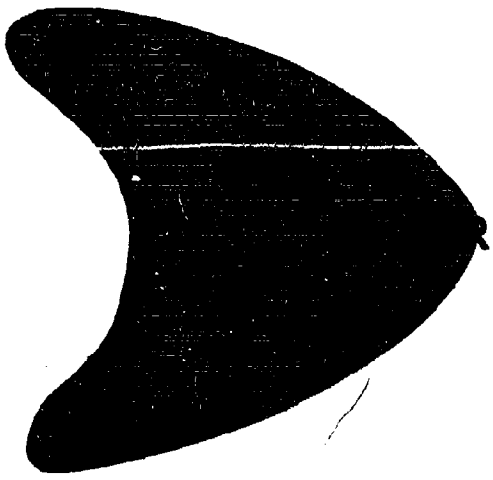
64-9



...RESS REPORT

SECOND QUARTER
OCTOBER - DECEMBER 1963

DEVELOPMENT OF THIN ORGANIC ROLLED FILM CAPACITOR

UNION CARBIDE

UNION CARBIDE CORPORATION
LINDE DIVISION
KEMET DEPARTMENT

RESEARCH AND DEVELOPMENT WORK ON DEVELOPMENT OF THIN ORGANIC ROLLED FILM CAPACITOR

BUREAU OF SHIPS CONTRACT NObsr-89519

SECOND QUARTERLY PROGRESS REPORT

OCTOBER 1, 1963 - DECEMBER 31, 1963

DEVELOPMENT OF THIN ORGANIC ROLLED FILM CAPACITOR

BUREAU OF SHIPS CODE 606/681A2

SUBJECT

Bureau of Ships Contract NObsr-89519
Quarterly Research and Development Report,
October 1, 1963 - December 31, 1963

REFERENCE

Project Serial No. SR0080302 ST 9636

PROGRAM OBJECTIVES

To develop a capacitor, using ML-1 film as the dielectric, capable of 100 volt operation over the temperature range of -55 to 170°C, which is twenty times smaller than equivalent CQ05 per MIL Specification MIL-C-19978B. Such capacitor to exhibit dissipation of .01%; insulation resistance of at least 15 ohm farads at 170°C; temperature coefficient of less than 250 ppm/°C; 250% dielectric withstanding voltage; no capacitance shift with frequenty; less than 5% change in capacitance after life test.

Approved by:

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J. S. Wagener, Manager
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I. Substrate Preparation

The first phase of the study to improve the surface of the aluminum substrate has been initiated. The areas in which active work has been done include:

A. Surface Decontamination
B. Mechanical Smoothing
C. Electrochemical Polishing

The processing of foils for surface decontamination has been carried out using a makeshift machine since the machine designed for this operation was not available until December 20, 1963.

A. Surface Decontamination

Special aluminum foils have been obtained 0.0006" thick x 1" wide both sides bright for these trials. These foils have been cleaned using trichloroethylene baths. The cleaning conditions were as follows:

1. One pass bath at approximately 1 ft/min foil speed.
2. Two pass bath at approximately 1 ft/min foil speed.
3. One pass bath at approximately 1/2 ft/min foil speed.

The foil speed through the bath was not constant since the machine used operated at fixed winding spool speeds. All operations were performed at room temperature (71-74°F). The trichloroethylene was air dried as the foil was rewound. The quantities cleaned in each manner were limited to 200 feet due to rewind difficulties with the processing machine.

The cleaned foils have been shipped to the Union Carbide Plastics Division to be coated with ML-1 film approximately 2 μ thick. The coated foils will be evaluated electrically and made into roll capacitors for comparative testing.

The new foil handling machine has been checked to determine its capability to rewind large rolls of foil and has been found satisfactory.

B. Mechanical Smoothing

A manufacturer has been located that has a special rolling mill which is claimed to be capable of producing 0.00025" thick aluminum foil bright on both sides. Arrangements have been made to make trial runs on this rolling mill early in January. The surface roughness of the resulting foils will be determined and compared to presently available foils.

C. Electrochemical Polishing

Aluminum foils of special electrolytic grades and purities have been ordered and processing will begin as soon as the new foil handling machine is equipped with chemical resistant guide rollers.

II. Evaluation of Coated Foils

Foils No. 10-17 and 10-18 were purchased for this contract and were used to assemble capacitors for evaluation (Batch USN-1). These foils (440 ft total) were 0.00025" thick x 1" wide before coating. The thickness and breakdown voltage of the foils were measured on the equipment described in the First Quarter Progress Report. The test methods were standardized as a raw material quality control test (see Appendix).

III. Slitting

Slitting of ML-1 coated foils has been carried out at Hamilton Watch Company. A search is still under way for a manufacturer to supply a slitting machine adequate for this material.

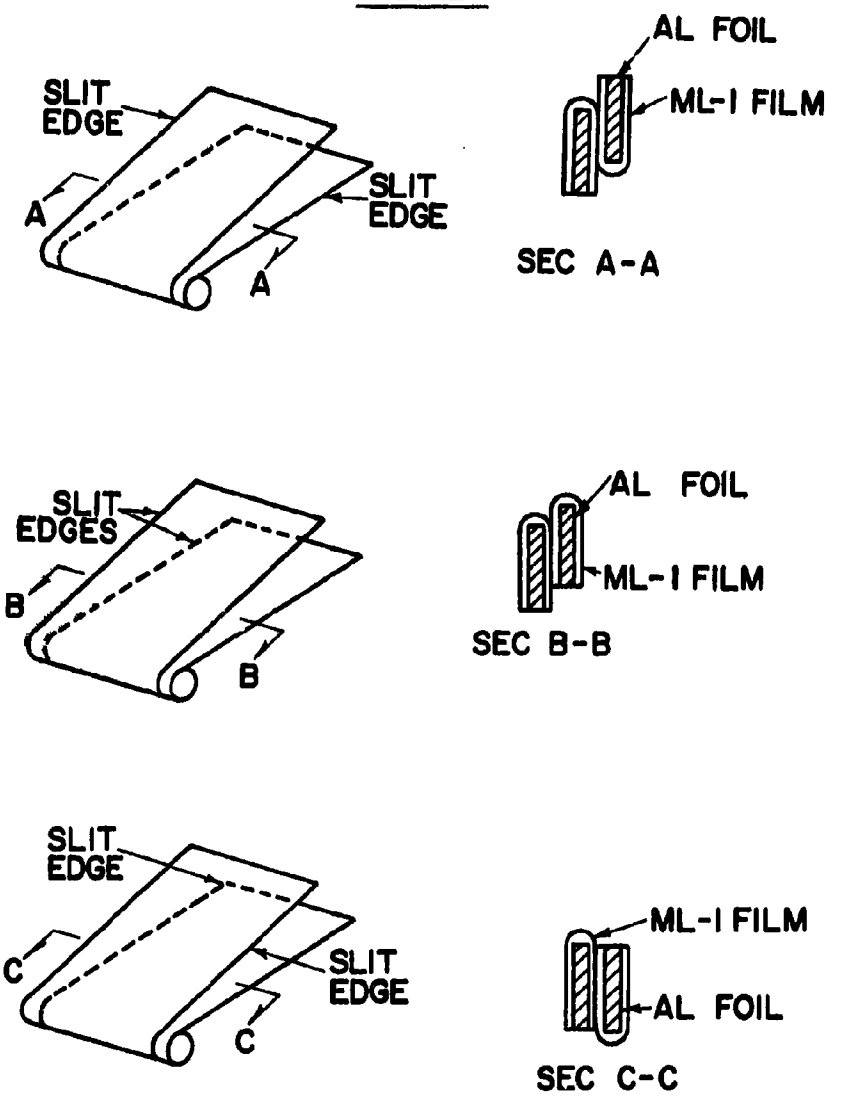
Coated foils have been slit to 1/4, 1/2, 3/4, 1-1/4 and 1-1/2" from 1" or 2" stock. The capacitors rolled from the slit foils exhibited the same electrical properties and failure rates as capacitors rolled from 1" wide unslit stock when these slit edges were placed in the margin of the roll (see Figure 1).

A difference in voltage breakdown was anticipated when the slit edges were placed inside the roll as seen in Figure 1. This is based on the reduction of dielectric thickness in the area of the slit edge. Experimental results on capacitors made with one and two slit edges in the roll gave the yields shown in Table I when tested at 140 VDC at room temperature.

TABLE I

	Control	One Slit Edge in Roll	Two Slit Edges in Roll
Trial 1	80%	45%	0%
Trial 2	84%	61%	40%

FIGURE 1


SLIT EDGE
A
SLIT EDGE
A
AL FOIL
ML-I FILM
SEC A-A
SLIT EDGES
B
B
AL FOIL
ML-I FILM
SEC B-B
SLIT EDGE
C
SLIT EDGE
C
ML-I FILM
AL FOIL
SEC C-C

From these data it is conclusive that slit edges of coated foil must not be rolled in the capacitor. Methods are being investigated to remove the exposed aluminum at the slit edge which would permit better material utilization by multiple slitting. The preliminary parts from these tests are now on life test at 50 volts and 170 °C.

IV. Termination

The termination of the capacitor rolls by flame spraying and soldering was not considered adequate since some of the parts sprayed did not attain sufficient bond strength on one end to withstand handling. Tensile tests indicated 3-4 pounds of bond strength after soldering the lead. By proper grinding with 80 grit abrasive and improved control of the flame spray, the bond strength was increased to 12 pounds minimum measured by the same tensile test. The solderability also remained very good. The melting point of the solder has been increased from 60/40 alloy (183 °C melting point) to 95% tin-5% antimony (232 °C melting point). With these changes the processing problems at termination have been eliminated.

Vibration tests were made to check the mechanical stability of the capacitors. Capacitors were subjected to loads of 15 and 30 g for 8 hours at a frequency of 5 to 2000 cps and also a 50 g, 11 milliseconds shock test. No failures occurred during or as a result of these tests.

V. Encapsulation

The capacitors are hermetically sealed in nickel-silver cans (65% copper-17% zinc-18% nickel). New cans are being made in the sizes shown in Table II; delivery will be complete by the end of January on all sizes.

TABLE II

L	OD	ID
0.750	0.195	0.175
0.750	0.240	0.220
1.000	0.290	0.270
1.000	0.345	0.325
1.250	0.398	0.378
1.500	0.398	0.378
1.750	0.398	0.378

As these cans become available, capacitors of other microfarad ratings will be made.

VI. Life Testing

ML-1 capacitors have been life tested at temperatures of 125 and 170°C and voltages of 50, 70, and 100 volts. A failure detection system is used which automatically indicates time of failure and panel identification. This is done without disturbance to other units or interruption of the test. From the panel identification code, test conditions and elapsed time to failure can be determined. A schematic of the system is shown in Figure 2. A test panel for one test condition, i.e., 50 volts, 170°C, has 45 test capacitor positions with series diodes and a common SCR triggering circuit which actuates the clock printer. By multiplexing the six code characters of the printer, individual identification of more than 50 panels (2,250 pcs) is possible.

The main objective of the life testing done to date has been the evaluation of many material, design and processing parameters rather than to establish the failure rate of a large number of capacitors of similar genesis.

VII. Sample Capacitors

Capacitors were constructed from coated foils 10-16 and 10-17 using the best methods available to date. The detailed Construction Information section (Item B) outlines these methods. Electrical measurements have been made on these parts and life tests started at 50 VDC and 170°C.

A summary of average electrical values is shown in the following table:

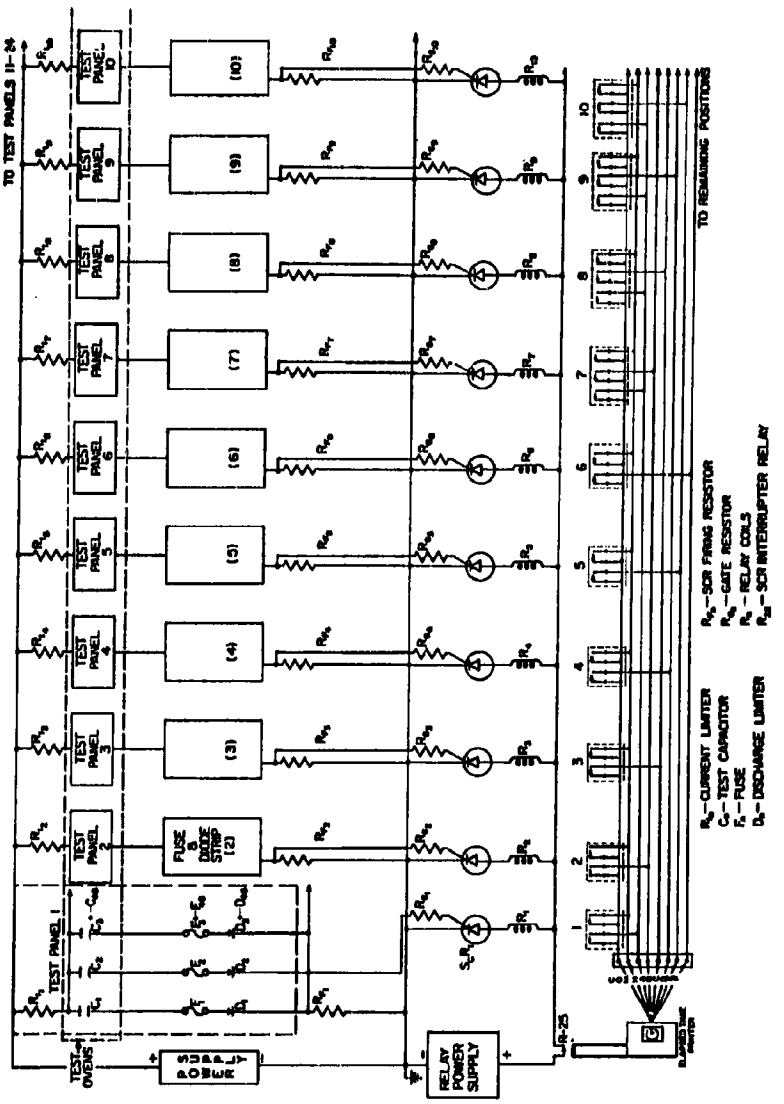
TABLE III

Cap. - μf at 1 KC	DF - % 1 KC	DA* %	IR at 170°C megohm-μf	TCC - ppm/°C		
				-55	+85	+150
0.1083	0.014	0.082	1.3×10^2	-126	-59	-63

* Dielectric Absorption

For detailed measurements on each capacitor see appended Table VI.

FIGURE 2


TO TEST PANELS 11-24
TEST PANEL 10
TEST PANEL 9
TEST PANEL 8
TEST PANEL 7
TEST PANEL 6
TEST PANEL 5
TEST PANEL 4
TEST PANEL 3
TEST PANEL 2
TEST PANEL 1
FUSE & DIODE STRIP (2)
TEST OVENS
RELAY POWER SUPPLY
TO REMAINING POSITIONS
R_{sc} – SCR FIRING RESISTOR
R_{sg} – GATE RESISTOR
R_r – RELAY COILS
R_{sr} – SCR INTERRUPTER RELAY
R_c – CURRENT LIMITER
C – TEST CAPACITOR
F – FUSE
D_c – DISCHARGE LIMITER

A. Coated Foil Data

TABLE IV

Foil No.	Thickness		Breakdown Volts	
	Bright	Dull	Bright	Dull
10-16	2.22 μ	2.17 μ	160-650 (417 avg.)	250-800 (596 avg.)
10-17	2.25 μ	2.17 μ	300-600 (519 avg.)	150-920 (507 avg.)

See Figures 3 and 4.

B. Construction Information

Batch No. USN-1
Foils Used: No. 10-16 & No. 10-17 (See Foil Testing Sheet)
Breakdown Voltage Foil: 500 Volts Average (See Foil Testing Sheet)
Coating Thickness: 2.2 μ - Average from Foil Testing Sheet
Foil Width: 1"
Target Capacitance: 0.10 μf
Pieces Rolled: 116
Arbor Size: 0.060"
Encapsulant: Dow Corning Sylgard 183
Tape: Teflon 3M No. 69
Solder: 95% Tin-5% Antimony
Processing Losses After:

Rolling	0	
Grinding	2	
Flame Spray	0	
Lead Attach.	0	
Canning	0	
Voltage	0	
Conditioning	2	- See Note

Note: Conditioning losses were due to loss of terminations. Parts were opened leads attached and reassembled. These parts are included in the data as Nos. 15 and 54.

Note: Roll Size - 0.170 O.D. x 1.10" Long
Can Size - 0.290 x 1.50" Long
Oversized can used as a matter of availability.

FIGURE 3

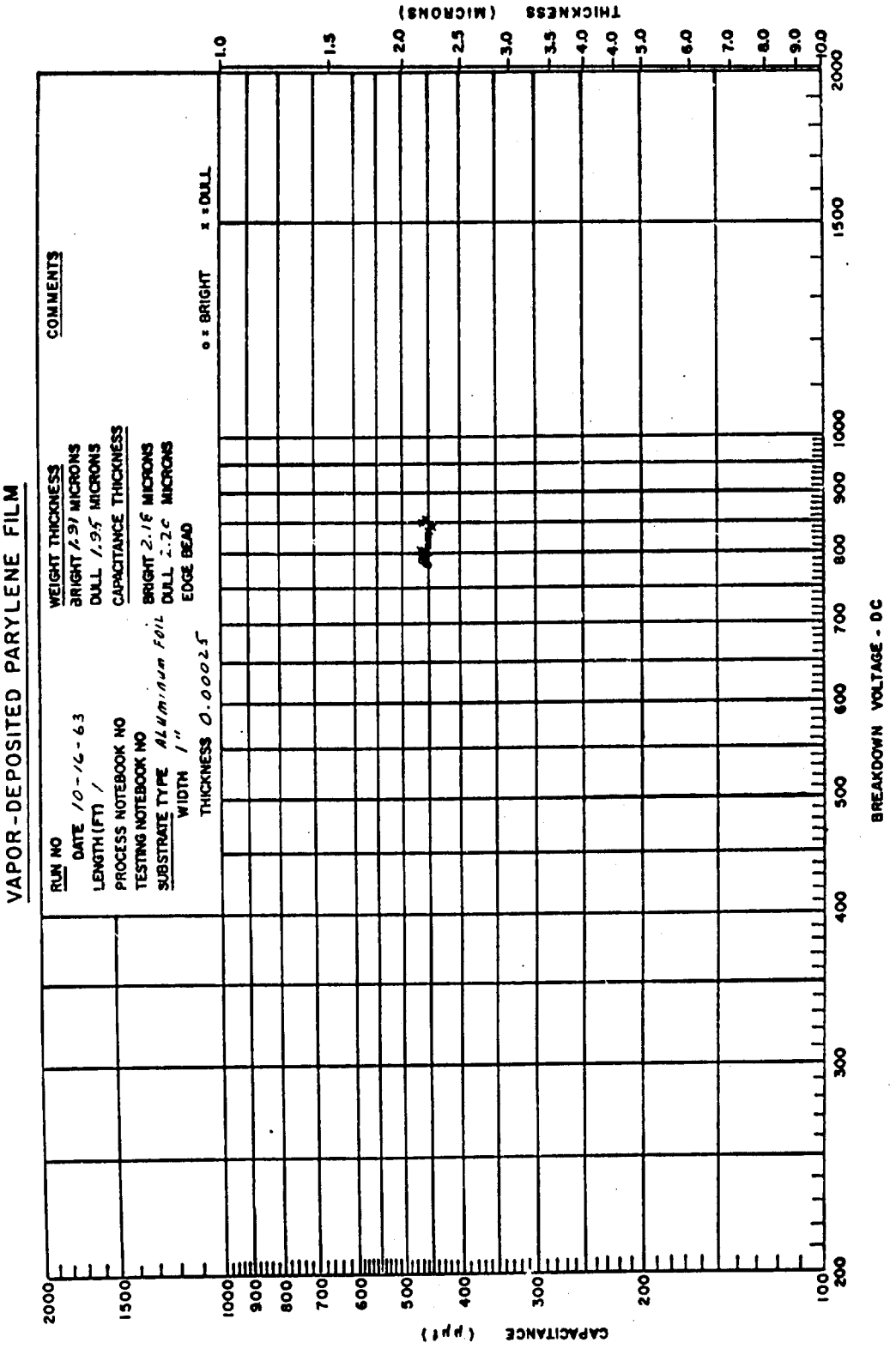
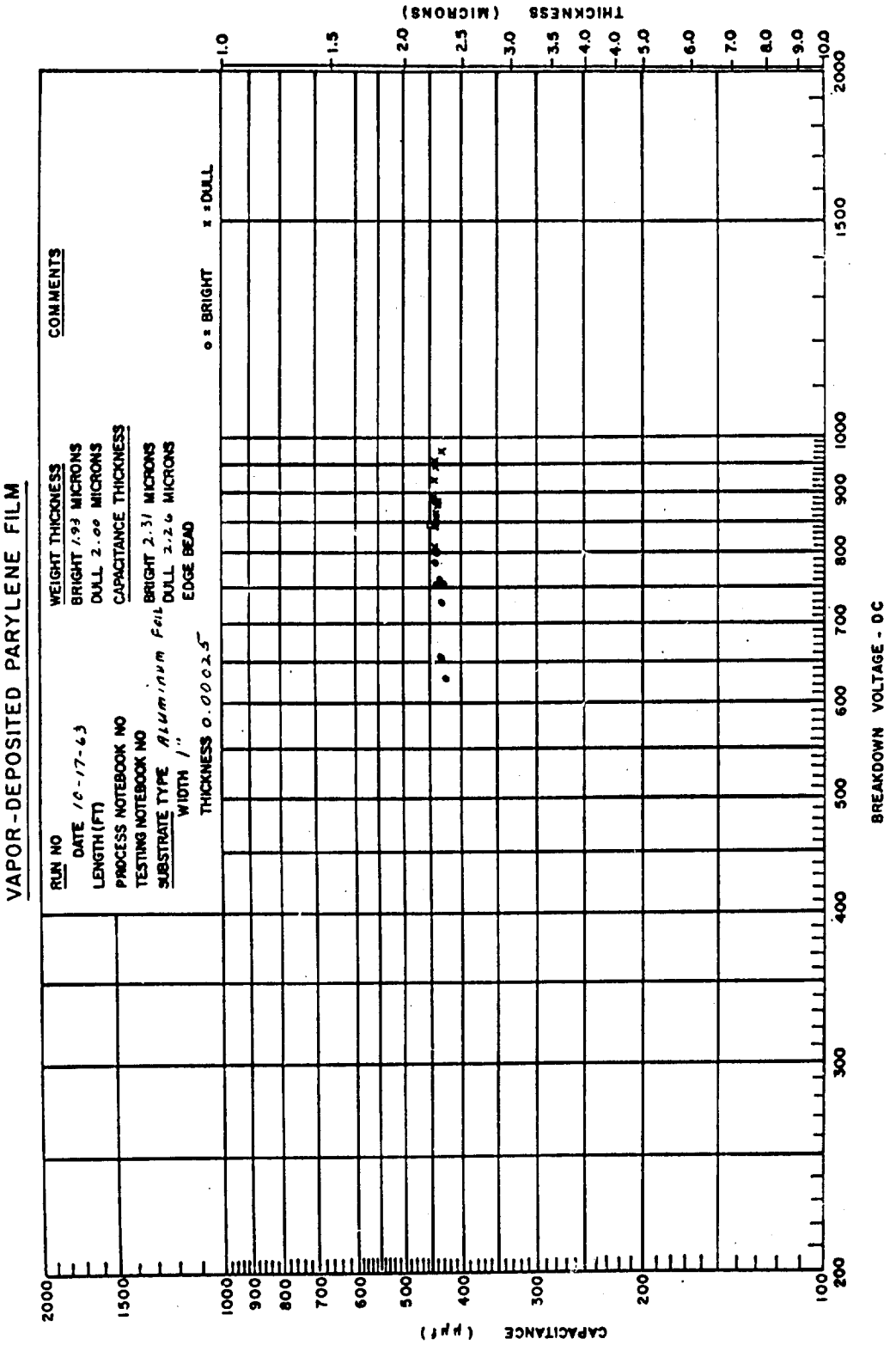

VAPOR-DEPOSITED PARYLENE FILM
RUN NO
DATE 10-16-63
LENGTH (FT) /
PROCESS NOTEBOOK NO
TESTING NOTEBOOK NO
SUBSTRATE TYPE Aluminum Foil
WIDTH 1"
THICKNESS 0.00025"
WEIGHT THICKNESS
BRIGHT 1.91 MICRONS
DULL 1.95 MICRONS
CAPACITANCE THICKNESS
BRIGHT 2.18 MICRONS
DULL 2.2C MICRONS
EDGE BEAD
COMMENTS
o = BRIGHT x = DULL
THICKNESS (MICRONS)
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
2000 1500 1000 900 800 700 600 500 400 300 200 100
CAPACITANCE (ppf)
2000 1500 1000 900 800 700 600 500 400 300 200 100
BREAKDOWN VOLTAGE - DC

FIGURE 4


VAPOR-DEPOSITED PARYLENE FILM
RUN NO
DATE 10-17-63
LENGTH (FT)
PROCESS NOTEBOOK NO
TESTING NOTEBOOK NO
SUBSTRATE TYPE Aluminum Foil
WIDTH 1"
THICKNESS 0.00025"
WEIGHT THICKNESS
BRIGHT 1.93 MICRONS
DULL 2.00 MICRONS
CAPACITANCE THICKNESS
BRIGHT 2.31 MICRONS
DULL 2.24 MICRONS
EDGE BEAD
COMMENTS
o = BRIGHT x = DULL
THICKNESS (MICRONS)
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
2000
1500
1000
900
800
700
600
500
400
300
200
100
CAPACITANCE (μμf)
BREAKDOWN VOLTAGE - DC

C. Dissipation Factor Shift with Temperature

A new piece of apparatus has been constructed to test dissipation factor at various temperatures. This apparatus is comprised of a temperature test chamber which is connected to a General Radio bridge Model 716A using 1/4" bus bar less than one foot long to obtain low lead resistance. The dissipation factors measured on this apparatus were found to be identical with the values obtained when connected directly to the bridge. Representative dissipation factors measured over the temperature range of -195 °C (liquid N_2) to +170 °C are shown in the following table:

TABLE V

Dissipation (%) Measured at 1 KC				
-196 °C	-55 °C	25 °C	150 °C	170 °C
0.011	0.034	0.011	0.018	0.025

The improved apparatus described here makes possible much higher accuracy than previously obtained. The results indicate only minor changes in dissipation factor over the temperature range used.

APPENDIX

ML-1 Capacitors - Quality Control Test - Development Phase

Equipment

(a) Ballantine Capacitance Meter Model 520
(b) Microdot BDV Tester Model 1901-A
(c) Test Fixture
(d) Mercury Probe

Materials

(a) Coated Foil Stock
(b) Clean Mercury

QC Instructions ML-1 Coated Aluminum Foil

1. Each roll of coated foil shall be sampled and checked for coating thickness and breakdown voltage on both sides.
2. The sample shall consist of 12" to 14" of coated stock which is free from wrinkles and creases.
3. Procedure -

The sample shall be laid across a smooth glass or lucite block and a calibrated electrode (see attached figure) placed on the surface and filled to the top with mercury. A small area at the end of the foil shall be bared by peeling away the ML-1 coating and electrical connection made at this point. The Microdot breakdown voltage tester shall be connected between the bared foil and the mercury electrode. Three BDV measurements shall be made at each test spot using a 10 μa current limit. The Microdot tester shall then be disconnected and the capacitance measured by connecting the Ballantine capacitance meter between the bared foil and the calibrated mercury electrode. The Microdot tester shall then be reconnected and the BDV measured using the 1 ma current limit. Three BDV measurements shall be made at each test spot using 1 ma current limit. The highest value at 1 μa and 1 ma current limits shall be recorded as BDV for each test spot.

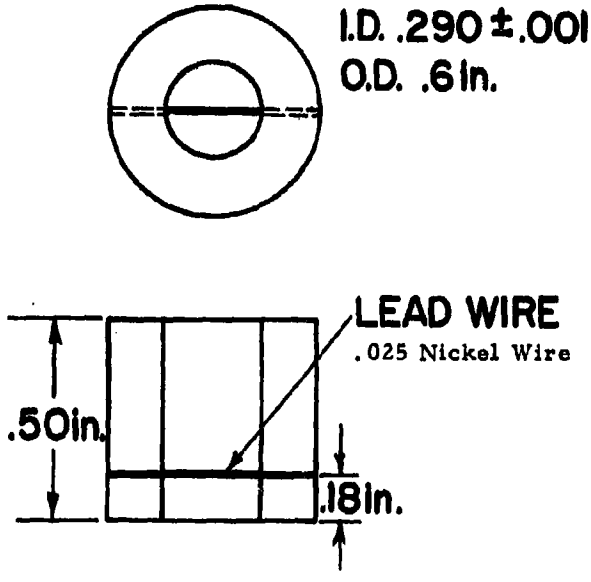
At least six such measurements shall be made on each side of the sample. A range and average shall be determined for capacitance and BDV on each side. The coating thickness shall be determined from the capacitance measurement by using the formula

$$\frac{1000}{pf} = \text{film thickness in microns.}$$

When moving the mercury electrode from one test area to another it shall be lifted off the foil surface to prevent damage to the coating and false readings.

FIGURE 5

MERCURY ELECTRODE CELL



Material - Lucite
Polish Bottom - Break Edge

K-147

TABLE VI

TEST SUMMARY

BATCH: USN-1

No.	Life Test Hours	After Condition Cap. - μf	% Dis.	TCC -55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D. A.
1	0 250 500 1000	Loss on Grinding							
2	0 250 500 1000	.10136 .10350	.02 .02	-116 -	-50 -	- 57 -	x -	1.17×10^3 1.6×10^2	-
3	0 250 500 1000	.10208 .10440	.01 .02	-126 -	-56 -	- 52 -	x -	1.60×10^3 2.0×10^2	-
4	0 250 500 1000	.10456 Short at 250 Hours L.T.	.012	-131	-54	- 50	x	2.0×10^1	-
5	0 250 500 1000	.11119 .11336	.012 .02	-135 -125	+15 -52	- 62 - 90	x -	1.3×10^3 1.3×10^3	.071 .124
6	0 250 500 1000	.11028 .11256	.075 .02	-128 -	-64 -	- 65 -	x -	9.8×10^2 4.1×10^2	-
7	0 250 500 1000	.11619 .1178	.01 .02	-130 -	-80 -	- 67 -	x -	1.02×10^3 1.3×10^3	-

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
8	0	.10694	.015	-105	-46	- 48	x	2.5×10^3	-
	250	.10892	.02	-	-	-	-	3.8×10^3	
	500								
	1000								
9	0	.10071	.01	-133	-49	- 53	x	3.75×10^1	-
	250	.10332	.02	-	-	-	-	1.1×10^3	
	500								
	1000								
10	0	.11097	.02	-129	-67	- 64	x	3.0×10^3	-
	250	.11840	.085	-	-	-	-	4.5×10^2	
	500								
	1000								
11	0	.10926	.01	-133	-80	- 97	x	9.2×10^2	-
	250	.11084	.02	-	-	-	-	5.2×10^2	
	500								
	1000								
12	0	.10886	.022	-137	-59	- 74	x	1.05×10^3	-
	250	Short at 250 Hours L.T.							
	500								
	1000								
13	0	.10764	.015	-127	-55	- 48	x	Open	Open
	250	Not on L.T. Due to Open							
	500								
	1000								
14	0	.10893	.015	-105	-52	- 42	x	2.5×10^3	
	250	.11119	.02	-	-	-	-	7.3×10^2	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - μf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
15	0 250 500 1000	.10865 Not on L. T. Due to Short	.012	- 56	-09	+ 26	SHT	SHT	SHT
16	0 250 500 1000	.1155 .1176	.012 .04	-130 -134	-27 -68	- 58 -105	x -	1.4×10^3 5.2×10^2	.076 .090
17	0 250 500 1000	.11383 .1158	.01 .025	-142 -	-78 -	- 42 -	x -	9.8×10^2 2.5×10^2	
18	0 250 500 1000	.10226 Short at 250 Hours L.T.	.012	-113	-45	- 03	x	2.5×10^3	.138
19	0 250 500 1000	.10568 .10778	.01 .075	-145 -146	-58 + 5	- 12 - 59	x -	3.75×10^3 3.5×10^3	.077 .073
20	0 250 500 1000	.10496 Not on L. T. - Open	.01	-140	-78	- 48	x	Open	Open
21	0 250 500 1000	.10366 .10602	.01 .02	-131 -132	-60 - 7	0 - 58	x -	4.5×10^3 1.0×10^3	.102
22	0 250 500 1000	.11533 .11720	.01 .02	-142 -	-80 -	- 87 -	x -	7.76×10^2 1.0×10^4	-

x = Passed 140 V, 2 Min. Test

D. A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
23	0	.11270	.012	-134	-82	- 95	x	2.8 x 10^2	-
	250	Short on L.T. at 5 Hours							
	500								
	1000								
24	0	.11316	.012	-147	-80	- 29	SHT	SHT	SHT
	250	Not on L.T. Due to Short							
	500								
	1000								
25	0	Loss on Grinding							
	250								
	500								
	1000								
26	0	.11276	.012	-148	-81	- 42		2.5 x 10^3	.107
	250	.1152	.02	-137	-70	-110	-	7.3 x 10^2	.073
	500								
	1000								
27	0	.11037	.01	-132	-67	- 34	x	1.6 x 10^3	.053
	250	.11264	.02	-124	-57	- 95	-	1.1 x 10^3	
	500								
	1000								
28	0	.11271	.01	-142	-87	- 50	SHT	SHT	SHT
	250	Not on L.T. Due to Short							
	500								
	1000								
29	0	.10408	.01	-135	-57	- 10	x	1.87 x 10^3	.076
	250	.10626	.02	-117	-29	- 72	-	1.6 x 10^3	
	500								
	1000								
30	0	.11050	.01	-138	-56	+ 07	x	1.46 x 10^3	.080
	250	.11290	.02	-115	-38	- 76	-	1.0 x 10^3	
	500								
	1000								

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
31	0	.10517	.01	-118	-45	+ 04	x	1.72×10^3	.044
	250	Short on L.T. at 5 Hours							
	500								
	1000								
32	0	.10589	.01	-137	-64	- 17	x	1.72×10^3	-
	250	.10857	.02	-130	-44	- 89	-	9.0×10^2	
	500								
	1000								
33	0	.10462	.012	-109	-45	- 83	x	1.6×10^3	-
	250	.10990	.105	- 46	+68	+ 40	-	4.9×10^2	Open
	500								
	1000								
34	0	.10518	.01	-117	-35	- 67	x	1.72×10^3	-
	250	.10706	.02	-	-	-	-	5.4×10^2	
	500								
	1000								
35	0	.11430	.01	-138	-88	-114	x	2.0×10^3	-
	250	.11640	.02	-	-	-	-	3.2×10^3	
	500								
	1000								
36	0	.10668	.017	-107	-49	- 80	x	4.1×10^3	-
	250	.10842	.02	-	-	-	-	2.8×10^3	
	500								
	1000								
37	0	.10671	.012	-120	-64	- 92	x	1.02×10^3	-
	250	Short on L.T. at 5 Hours							
	500								
	1000								
38	0	.1176	.015	-140	-90	-115	x	9.3×10^2	-
	250	.12110	.03	-	-	-	-	3.8×10^1	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170 °C IR Megohms	% D.A.
39	0	.11012	.02	-132	-72	- 84	x	6.6×10^2	-
	250	.11222	.02	-	-	-	-	1.07×10^2	
	500								
	1000								
40	0	.11200	.015	-133	-78	-102	x	1.87×10^3	-
	250	.11394	.02	-	-	-	-	2.7×10^2	
	500								
	1000								
41	0	.11341	.01	-123	-77	-108	x	8.3×10^2	-
	250	.11580	.02	-	-	-	-	7.0×10^2	
	500								
	1000								
42	0	.10836	.01	-105	+40	- 67	x	1.55×10^3	-
	250	.11013	.025	-	-	-	-	3.2×10^2	
	500								
	1000								
43	0	.1191	.018	-125	-95	-135	x	3.75×10^2	-
	250	Short at 250 Hours L.T.							
	500								
	1000								
44	0	.11288	.012	-	-	-	x	7.76×10^2	-
	250	.11520	.01	-	-	-	-	3.5×10^2	
	500								
	1000								
45	0	.10747	.01	-104	-39	- 64	x	2.8×10^3	-
	250	.10916	.04	-	-	-	-	1.1×10^3	
	500								
	1000								
46	0	.10676	.017	-	-	-	x	6.4×10^2	-
	250	.10815	.02					3.2×10^2	
	500								
	1000								

x = Passed 140 V, 2 Min. Test D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - μf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
47	0	.10304	.015	-109	-45	- 72	x	4.1×10^3	-
	250	.11680	.110	-	-	-	-	6.5×10^2	
	500								
	1000								
48	0	.1221	.02	-	-	-	x	1.4×10^3	-
	250	.1234	.025	-	-	-	-	4.5×10^2	
	500								
	1000								
49	0	.10358	.018	-	-	-	x	Open	Open
	250	Not on L.T. due to Open							
	500								
	1000								
50	0	.10091	.015	-	-	-	x	8.0×10^2	-
	250	.10197	.025	-	-	-	-	3.8×10^2	
	500								
	1000								
51	0	.11238	.01	-127	-16	-100	x	Open	Open
	250	Not on L.T. due to Open							
	500								
	1000								
52	0	.10448	.01	-133	+16	- 90	x	1.72×10^3	-
	250	.10707	.02	-	-	-	-	9.8×10^2	
	500								
	1000								
53	0	.10300	.01	-138	-63	-102	x	3.75×10^3	-
	250	.11780	.11	-	-	-	-	1.6×10^2	
	500								
	1000								
54	0	.10652	.01	-	-	-	x	5.1×10^2	-
	250	.10876	.02	-	-	-	-	8.7×10^1	
	500								
	1000								

x = Passed 140 V, 2 Min. Test D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC -55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
55	0	.10519	.01	- 89	-40	- 73	x	3.75×10^3	-
	250	.10654	.02	-	-	-	-	1.1×10^3	
	500								
	1000								
56	0	.11256	.012	-	-	-	x	2.25×10^3	-
	250	Short on L.T. at 5 Hours							
	500								
	1000								
57	0	.1159	.01	-140	-94	-140	x	1.25×10^3	-
	250	.1210	.055	-	-	-	-	2.1×10^3	
	500								
	1000								
58	0	.10721	.015	-	-	-	x	2.4×10^3	-
	250	.10859	.025	-	-	-	-	6.6×10^2	
	500								
	1000								
59	0	.11046	.015	-	-	-	x	3.0×10^2	-
	250	.11280	.04	-	-	-	-	3.2×10^2	
	500								
	1000								
60	0	.10620	.015	-	-	-	x	1.72×10^3	-
	250	.10892	.03	-	-	-	-	1.6×10^3	
	500								
	1000								
61	0	.1148	.018	-	-	-	x	1.6×10^3	-
	250	.11660	.02	-	-	-	-	7.3×10^2	
	500								
	1000								
62	0	.11245	.012	-	-	-	x	1.46×10^3	-
	250	.11348	.02	-	-	-	-	1.3×10^3	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - μf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
63	0	.11002	.01	-	-	-	x	1.3×10^3	-
	250	.11097	.02	-	-	-	-	1.3×10^3	
	500								
	1000								
64	0	.1151	.018	-	-	-	x	7.0×10^2	-
	250	Short at 250 Hours L.T.							
	500								
	1000								
65	0	.1168	.018	-	-	-	x	6.3×10^2	-
	250	.11780	.022	-	-	-	-	8.0×10^2	
	500								
	1000								
66	0	.1168	.018	-	-	-	x	1.02×10^3	-
	250	.1258	.090	-	-	-	-	1.5×10^2	
	500								
	1000								
67	0	.1176	.018	-	-	-	x	7.0×10^2	-
	250	.1194	.020	-	-	-	-	5.1×10^2	
	500								
	1000								
68	0	.11257	.01	-	-	-	x	9.2×10^2	-
	250	.11464	.018	-	-	-	-	7.0×10^2	
	500								
	1000								
69	0	.11279	.01	-	-	-	x	5.2×10^2	-
	250	.11492	.02	-	-	-	-	1.7×10^3	
	500								
	1000								
70	0	.10767	.01	-	-	-	x	3.75×10^3	-
	250	.10923	.02	-	-	-	-	5.6×10^2	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
71	0	.10402	.010	-	-	-	x	1.96×10^3	-
	250	.10506	.02	-	-	-	-	7.5×10^2	
	500								
	1000								
72	0	.10423	.012	-	-	-	x	2.4×10^3	-
	250	.10620	.02	-	-	-	-	8.3×10^2	
	500								
	1000								
73	0	.10904	.012	-	-	-	x	8.0×10^2	-
	250	.10997	.022					6.2×10^1	
	500								
	1000								
74	0	.10536	.012	-	-	-	x	1.3×10^3	-
	250	.10648	.02					3.8×10^2	
	500								
	1000								
75	0	.10230	.012	-	-	-	x	8.7×10^2	-
	250	.10358	.02					2.3×10^2	
	500								
	1000								
76	0	.11287	.01	-	-	-	x	6.2×10^2	-
	250	.11492	.018					2.7×10^3	
	500								
	1000								
77	0	.10827	.015	-	-	-	x	4.9×10^2	-
	250	.10984	.022					7.0×10^2	
	500								
	1000								
78	0	.10601	.012	-	-	-	x	6.4×10^2	-
	250	.11206	.015					7.5×10^2	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
79	0	.10661	.015	-	-	-	x	6.2×10^2	-
	250	.10754	.02	-	-	-	-	2.7×10^2	
	500								
	1000								
80	0	.10918	.01	-	-	-	x	3.2×10^3	-
	250	.11054	.02	-	-	-	-	1.5×10^3	
	500								
	1000								
81	0	.10341	.01	-	-	-	x	1.5×10^3	-
	250	.10452	.03	-	-	-	-	3.8×10^1	
	500								
	1000								
82	0	.11062	.012	-	-	-	x	5.4×10^2	-
	250	.11202	.02	-	-	-	-	6.7×10^2	
	500								
	1000								
83	0	.10200	.01	-	-	-	x	1.96×10^3	-
	250	.10330	.02	-	-	-	-	4.1×10^2	
	500								
	1000								
84	0	.10552	.012	-	-	-	x	4.7×10^2	-
	250	.10649	.03	-	-	-	-	2.3×10^2	
	500								
	1000								
85	0	.11030	.012	-	-	-	x	4.8×10^2	-
	250	.11110	.02	-	-	-	-	2.5×10^2	
	500								
	1000								
86	0	.10904	.012	-	-	-	x	7.0×10^2	-
	250	.11017	.02	-	-	-	-	8.3×10^2	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
87	0	.10471	.013	-	-	-	x	5.6×10^2	-
	250	.10588	.022	-	-	-	-	5.1×10^2	
	500								
	1000								
88	0	.10856	.015	-	-	-	x	1.17×10^3	-
	250	.10980	.025	-	-	-	-	2.8×10^2	
	500								
	1000								
89	0	.10570	.012	-	-	-	x	Open	Open
	250	Not on L.T. due to Open							
	500								
	1000								
90	0	.10839	.012	-	-	-	x	8.0×10^2	-
	250	.10940	.085	-	-	-	-	1.6×10^3	
	500								
	1000								
91	0	.11238	.01	-	-	-	x	1.7×10^3	-
	250	.11323	.018	-	-	-	-	4.1×10^2	
	500								
	1000								
92	0	.10231	.012	-	-	-	x	1.3×10^3	-
	250	.10351	.022	-	-	-	-	1.1×10^3	
	500								
	1000								
93	0	.11273	.015	-	-	-	x	1.3×10^2	-
	250	Short on L.T. at 5 Hours							
	500								
	1000								
94	0	.11206	.013	-	-	-	x	5.6×10^2	-
	250	.11324	.022	-	-	-	-	2.0×10^2	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +15°*	140 VDC 2 Min. Voltage	170°C IR Megohms	% D.A.
95	0	.10543	.012	-	-	-	x	7.4 x 10^2	-
	250	.10637	.020	-	-	-	-	1.7 x 10^2	
	500								
	1000								
96	0	.11018	.012	-	-	-	x	1.7 x 10^3	-
	250	.11181	.022	-	-	-	-	7.0 x 10^2	
	500								
	1000								
97	0	.10858	.015	-	-	-	x	1.6 x 10^3	-
	250	.10990	.022	-	-	-	-	1.9 x 10^3	
	500								
	1000								
98	0	.10558	.01	-	-	-	x	1.7 x 10^3	-
	250	.10748	.021	-	-	-	-	6.3 x 10^2	
	500								
	1000								
99	0	.10756	.175	-	-	-	SHT	SHT	SHT
	250	Not on L. T. due to Short							
	500								
	1000								
100	0	.11059	.013	-	-	-	x	1.3 x 10^3	-
	250	.11169	.020	-	-	-	-	1.8 x 10^3	
	500								
	1000								
101	0	.10960	.01	-	-	-	x	6.4 x 10^2	-
	250	Not on L. T.							
	500								
	1000								
102	0	.10738	.01	-	-	-	x	1.25 x 10^3	-
	250	Not on L. T.							
	500								
	1000								

x = Passed 140 V, 2 Min. Test D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - μf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170 °C IR Megohms	% D.A.
103	0 250 500 1000	.10174 Not on L. T.	.01	-	-	-	x	1.25×10^3	-
104	0 250 500 1000	.10480 Not on L. T.	.01	-	-	-	x	8.8×10^2	-
105	0 250 500 1000	.11196 Not on L. T.	.012	-	-	-	x	1.4×10^2	-
106	0 250 500 1000	.09835 Not on L. T.	.013	-	-	-	x	1.87×10^2	-
107	0 250 500 1000	.10087 Not on L. T.	.01	-	-	-	x	3.2×10^2	-
108	0 250 500 1000	.09849 Not on L. T.	.012	-	-	-	x	1.3×10^3	-
109	0 250 500 1000	.10029 Not on L. T.	.01	-	-	-	x	1.13×10^3	-
110	0 250 500 1000	.09860 Not on L. T.	.01	-	-	-	x	8.5×10^2	-

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

TEST SUMMARY (Continued)

No.	Life Test Hours	After Condition Cap. - µf	% Dis.	TCC - 55°	TCC +85°	TCC +150°	140 VDC 2 Min. Voltage	170 °C. IR Megohms	% D.A.
111	0	.09099	.01	-	-	-	x	1.2×10^3	-
	250	Not on L.T.							
	500								
	1000								
112	0	.09104	.012	-	-	-	x	9.8×10^2	-
	250	Not on L.T.							
	500								
	1000								
113	0	.09735	.01	-	-	-	x	1.5×10^3	-
	250	Not on L.T.							
	500								
	1000								
114	0	.10204	.01	-	-	-	x	1.02×10^2	-
	250	Not on L.T.							
	500								
	1000								
115	0	.1401	.02	-	-	-	SHT	SHT	SHT
	250	Not on L.T.							
	500								
	1000								
116	0	.1206	.02	-	-	-	x	2.8×10^2	-
	250	.1220	.03	-	-	-	-	1.0×10^3	
	500								
	1000								

x = Passed 140 V, 2 Min. Test

D.A. = Dielectric Absorption

Arithmetic Average							
0	.10833	.014	48/126	48/59	48/63*	104/1.3×10^4	10/.082
250	80/.11133	.029	10/121	10/44	10/79	80/9.4×10^2	
500							
1000							

* Pieces Measured/ppm/°C

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